



IGY BULLETIN

A monthly survey by the U. S. National Committee for the International Geophysical Year. Established by and part of the National Academy of Sciences, the Committee is responsible for the U. S. International Geophysical Year program in which several hundred American scientists are participating and many public and private institutions are cooperating.

Oceanographic Expedition Downwind

Bulletin No. 2 described briefly some of the objectives of the IGY Deep Water oceanographic program and some pre-IGY work in the Atlantic Ocean. Many institutions in the United States and other countries are participating in this work.

Another major IGY cruise in the Pacific, expedition "Downwind," got under way on October 21, 1957, when two vessels, the *Horizon* and the *Spencer F. Baird*, left San Diego, California, for the central and south Pacific. These research vessels are operated by the Scripps Institution of Oceanography, La Jolla, California.

Earlier Cruises

Previous Scripps expeditions have covered much of the north Pacific through the waters south of Alaska, to Japan, and back. The central Pacific regions, from Hawaii to the Marshall Islands, southward to Fiji and Tonga, and back via Samoa, the Society Islands, the Tuamotu Archipelago and the Marquesas Islands, have also been visited. The "Midpac" cruise of 1950, during which the mid-Pacific submarine mountain range was explored, worked predominantly in the region from 15°N to 40°N. The "Capricorn" expedition of 1952-53, a joint operation by the *Horizon* and *Baird*, lasted five and one-half months and reached about 26°S.

During these previous expeditions, much work related to the present IGY oceanographic

program was done. Extensive seismic refraction profiles were completed. In such operations one ship, the listening ship, lays out with hydrophones in the water while the other, the shooting ship, runs a line of seismic shots starting about 50 miles away from the listening ship. The shooting ship drops TNT charges ranging in size from several hundred pounds at the extreme limits of the line to one pound near the listening ship. This technique of exploration of the submarine crust has been used throughout most oceanic areas. Much effort has been devoted to study of the submarine crustal structure in areas of geologic interest, such as trenches, island arcs, fracture zones, isolated marine mountains, some of the great plateau areas, and undersea rises.

Other activities included in these expeditions are: taking cores of the bottom sediments; heat flow measurements through the sediments; surface current measurements with the geomagnetic electrokinetograph (GEK); deeper current observations with drogues; Nansen bottle casts for chemical studies and to obtain density data for use in calculating deep currents; underwater photography for study of marine life; drag and grab samples of the bottom in unsedimented areas; photographs of the bottom for geologic and biologic purposes; detailed bathymetry of trenches, sea mounts, and other features of topographic interest; ob-

servations of the magnetic field with towed magnetometers; and many kinds of marine biological work.

Downwind

The Downwind expedition will make most of the geophysical observations listed above as part of the IGY program to map the deep circulation of the oceans. The approximate track of the expedition is shown in Fig. 1. Oceanographic ships of Canada and the

Brown Bear of the University of Washington have covered areas north of the Scripps tracks as part of the plan to observe the currents in a long meridional profile. Ships of other countries, notably Australia, New Zealand, Japan, and Russia, have worked and are working in other areas of the Pacific as part of the IGY plan to obtain extensive coverage.

The leaders of the expedition are Henry W. Menard, Jr., and Robert L. Fisher,

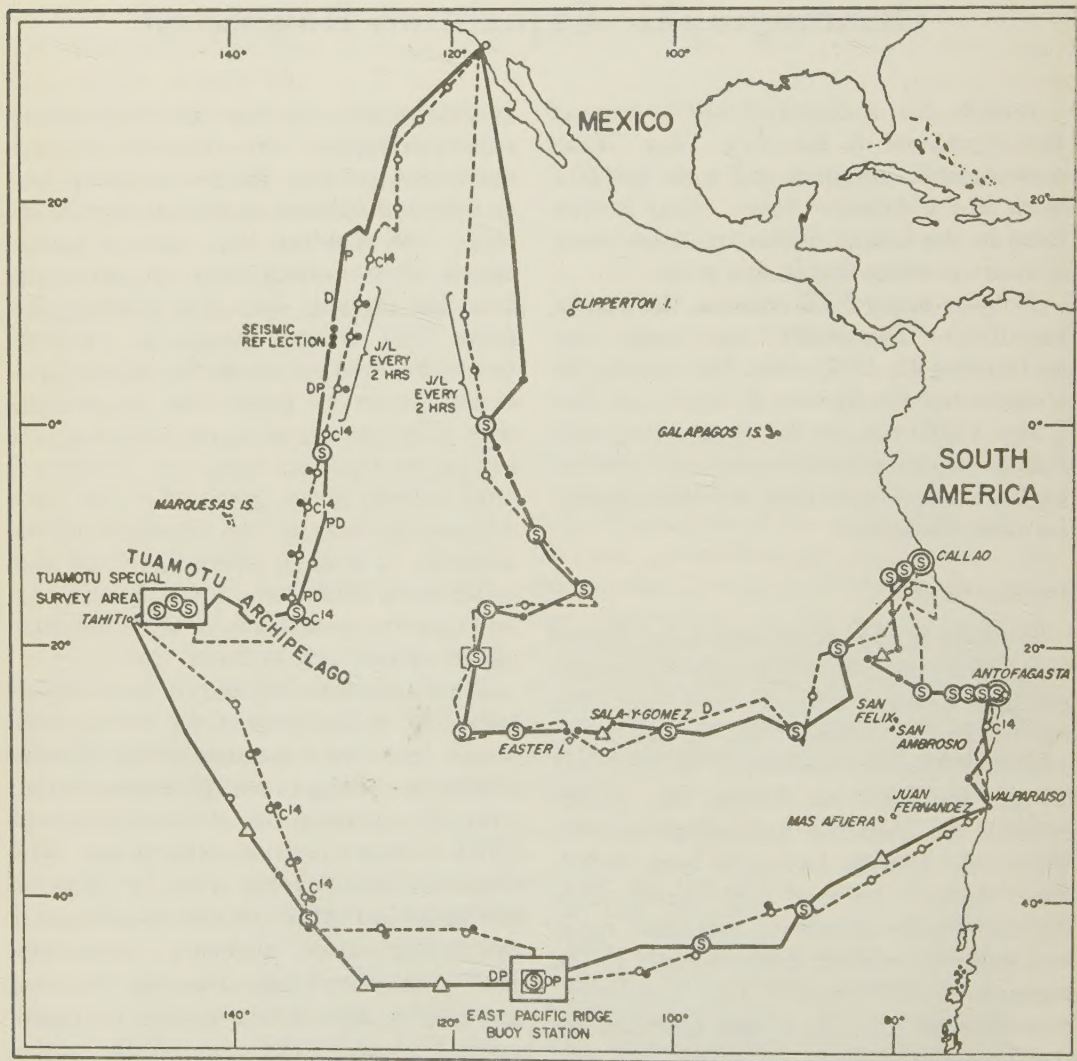


Fig. 1. Track Chart for IGY Oceanographic Expedition Downwind, October 1957–February 1958. Symbols: circled S—seismic refraction station, including piston core and heat flow measurement; double-circled S—seismic reflection station, including piston core; triangle—heat flow measurement, including core; black dot—gravity core; small circle—hydrographic cast; C¹⁴—radiocarbon sample; D—dredge haul; P—bottom photography.

of the Scripps Institution. The scientific party includes geologists, marine biologists, seismologists, chemists, oceanographers, and three physicians. J. N. Nanda, Chief Scientist of the Navy of the Republic of India, two Argentine, two Chilean, and two Peruvian scientists are expected to participate in the Valparaiso-to-Callao leg of the cruise.

Observational Program

During the Downwind expedition about 50 hydrographic casts will be made using Nansen bottles and reversing thermometers; special samples will be taken for analysis of radioactive isotopes. Seven groups of bottom photographs will be taken using an underwater camera developed by the U. S. Navy Electronics Laboratory.

A special probe developed at Scripps will be used at about 33 locations to measure heat flow through the oceanic sediments (only a small number of such measurements are now available). Heat flow data are useful in studies of crustal thickness and can also be applied to the study of the deep currents. During the Capricorn expedition, in 1953, the heat flow on the Albatross Plateau was unexpectedly high. This single measurement will be checked by revisiting the general area. If heat flow for oceanic rises proves to be higher than for basins or trenches, it would lend weight to suggestions that convection currents in the earth's interior might be responsible for tectonic effects at the crust.

These heat flow measurements are only part of the program of exploration of the marine crust. The cruise will establish the submarine topography of a profile along the 130°W meridian from the latitude of San Diego to about 50°S. About 15 dredge hauls will be made to collect samples as part of a study of the mineral resources of the sea floor, and almost 100 sediment cores are planned. Considerable attention will be devoted to a study of a most unusual topographic feature, the Tuamotu Archipelago. This group of atolls rises about one mile above the broad submarine ridges on which

they stand. The ridges themselves are about a mile and a half higher than the deep sea floor. Twenty-five seismic profiles are planned, with emphasis in this and other areas of special geologic interest, such as the Easter Island Rise and the narrow, deep Andean Trench just off the coast of Chile and Peru. The relief from the bottom of this trench to the top of the adjacent Andes is the greatest in the world.

Progress

H. W. Menard has summarized the work accomplished in the first two weeks of the expedition in a radio message to Scripps. He reported the following: nine deep hydrographic casts made; twenty-four sediment cores taken; three dredge hauls made; twenty-six seismic reflection stations and two seismic refraction stations occupied, including one using a small boat for shooting; 162 bathythermograph observations made; four bottom photographs made; and twenty seamounts discovered, six of which have been surveyed in detail. The program for assay of CO₂ in the air and in sea water has been essentially continuous.

Menard describes some interesting results of these early observations. The four bottom photographs, at depths between 13,200 and 14,400 ft, are the deepest yet obtained in the Pacific. They all show evidences of biological activity, such as trails, mounds, holes, or a pavement of manganese nodules, depending on sediment type. Seismic reflection shots show sediments 984 ft thick at 20°N, thickening to 1640 ft at the equator. A seismic refraction run at the equator revealed normal sound velocity in the sediments and deeper layers. A piston sediment core contained 33 ft of recent calcareous ooze, but the heat conductivity measurement was surprisingly low—0.4 microcal/cm²/sec. The daily averages of atmospheric CO₂ have ranged from 312 to 310 ppm.

Brief stops for refueling or local scientific investigation are scheduled at Papeete, Tahiti; Easter Island; Valparaiso, Chile; and Callao, Peru. The expedition will last

about four and one-half months and will cover almost 40,000 miles of track.

Expedition Vessels

As the La Jolla location does not permit berthing of seagoing vessels, the ships of the Scripps fleet are docked at the Navy Electronics Laboratory facility at Point Loma, contiguous to San Diego harbor.

The two vessels, *Horizon* and *Spencer F. Baird*, are converted 143-ft ocean-going tugs; they are steel-hulled, single-screw, diesel-electric vessels, with displacement of 934 tons and draft of 16'5" when loaded. The *Horizon* was acquired by Scripps in 1947, the *Baird* in 1951. The two ships have identical hulls but differing superstructures, and have been converted with somewhat different design.

The laboratory space on each ship is about 600 square feet. Each carries a crew of 17 and accommodates up to 15 in its scientific party.

For both ships, two twelve-cylinder Diesel engines driving separate direct-current generators and exciters supply power for two electric motors geared to a single shaft. The normal cruising speed is 11 knots with a range of about 10,000 miles. Food and water storage capacity allows about 45-50 days at sea between ports of call.

The after-decks or fantails of both ships are quite roomy; most equipment is lowered over the side from platforms either at the stern or at the side of the fantail immediately abaft the maindeck laboratory. Large A-frames have been constructed at the stern of each ship to handle the heavy and sometimes very bulky instruments. The A-frame of the *Horizon* rises about 28 ft from the

deck. The main 35-hp winch is capable of handling 20,000 ft of $\frac{1}{2}$ -inch wire. Other winches include a hydrographic winch with 20,000 ft of $\frac{3}{16}$ wire, a bathythermograph winch, and a special winch for electric cables, such as those used for the GEK and Thermitow instruments. The *Horizon*, usually the seismic shooting ship, has space for magazine storage of about 24 tons of explosives.

The A-frame on the *Baird*, with a platform about 35 ft above the fantail, is designed to handle loads of 20 tons. Her heavy winch, one of the three largest oceanographic winches in use today, is of the winding-machine type with electro-hydraulic drive and about 100-hp capacity. It is mounted immediately abaft the main deck laboratory. In conjunction with a storage reel mounted on the deck below, the winch handles up to 40,000 ft of tapered steel cable varying from $\frac{3}{8}$ to $\frac{3}{4}$ inch in diameter, and a shorter auxiliary cable of $\frac{1}{2}$ -inch diameter. Two bathythermograph winches and two power-driven gypsies complete the power equipment on the fantail. On the boat deck are mounted two hydrographic winches, with capacities of 20,000 and 30,000 ft of $\frac{3}{16}$ -inch wire. The *Baird* also has magazine storage space for explosives, and, as it is the listening seismic ship, the laboratory is equipped with seismic amplifying and recording equipment. A darkroom has been fitted out for immediate development of records and film.

Both ships are equipped with sonar, radar, considerable communications apparatus, loran, and echo sounders of both conventional type and newer precision models. The *Baird* also carries radio facsimile equipment.

Polar Ice and Snow Studies

The following article is based primarily on material supplied by Henri Bader of the US Army Snow, Ice, and Permafrost Research Establishment.

The major portion of the IGY effort in the field of glaciology is directed toward the study of ice and snow in the polar regions, particularly their glaciers and ice sheets. These studies will give information not only on the behavior of ice and snow under polar conditions but will also yield data on climate.

Two thirds of the area of the Greenland ice sheet and practically all of the Antarctic ice sheet are permanently dry. All precipitation is in the form of snow. Summer melt is rare and usually affects a surface layer only a few centimeters thick. Thus every snowfall, including everything that falls with it, is separately and safely filed away for future reference under later snowfalls.

The first man literally to dig into the 'files' was Sorge of the Wegener Expedition. At Eismitte in the center of the Greenland ice cap in 1930-31, he dug a 15-meter pit, counted the annual snow layers, and determined their density. During the past few years the records of the snow layers in Greenland have been examined in more detail and at greater depths by means of methods and instruments developed mainly by the US Army Snow, Ice and Permafrost Research Establishment (SIPRE).

Sorge's researches gave rise to a qualitative statement of the relationship of snow density, time, and climate. Sorge's Law is: At any given location in the dry snow region of a glacier, the density of the snow as a function of depth does not change with time unless the climate changes. SIPRE has given mathematical form to Sorge's Law and is expanding it to include the effects of changes in rate of precipitation and in temperature.

Snow is a poor conductor of heat; therefore, the amplitude of temperature variations in snow diminishes rapidly with depth. In Greenland the temperature at ten meters

depth is almost constant and is within one degree of the mean annual air temperature. Thus, measuring the snow temperature at this depth gives important climatic data without the necessity of long-term meteorological observations.

By digging a pit, counting annual layers, and measuring snow density as a function of depth below the surface, the amount of annual precipitation for many years can also be determined. The usual procedure involves digging a pit several meters deep, measuring temperature and noting stratigraphy in the pit wall, and taking closely-spaced samples with standard $\frac{1}{2}$ liter tubes for density measurements. For samples from greater depths, a hole is sunk from the bottom of the pit with a hand-operated core drill.

The identification of annual layers can be difficult unless there are thin ice crusts or other features to aid in distinguishing summer from winter layers. In Greenland it is possible to count annual layers almost without error, but in the Antarctic, there is much less precipitation and summers are much colder; therefore, the layers are thinner and not always characterized by ice crusts resulting from summer melt. It may be impossible to identify summer layers at high altitudes. A method of distinguishing between winter and summer layers by reason of the differing ratios of oxygen isotopes 16 and 18 in the snow has been developed by Samuel Epstein of the California Institute of Technology, but this method requires extensive laboratory work.

The tritium content of the snow can be used to estimate its age but only for snow which fell prior to 1954. Since then, hydrogen bomb tests have upset the natural tritium balance. Analysis for other radioactive contaminations in precisely dated snow layers in Greenland and in Antarctica will yield data on general atmospheric circulation since the first fission bombs were exploded

in 1945. It should also be possible to follow the degree of atmospheric contamination resulting from industrial activity by analyses of snows down to the layers which fell in preindustrial times.

Natural substances which fall with the snow and are buried beneath succeeding layers—such as volcanic ash, meteorites, spores, and bacteria—are extremely well preserved. Ash from the 1912 eruption of the Alaskan volcano Katmai was easily identified in a snow layer at a depth of 32 meters below the 1954 snow surface at a point 200 miles east of Thule, Greenland. It is doubtful that this 1912 deposit, which is almost certainly continuous over the whole of Greenland, will be found in the Antarctic, but the ash of the 1883 Krakatoa eruption may prove to be identifiable in both hemispheres.

The deepest penetration into the past during the IGY is planned for the US deep drilling program which has been entrusted to SIPRE. In preparation, SIPRE, in 1956, drilled to 300 meters at its experimental station on the Greenland ice sheet. Core recovery was very incomplete, the primary objective being the development of drilling techniques. A modified Failing "1500" drill rig and especially designed core barrels are used for this work. Ice cuttings are removed by compressed air which has been cooled so as to prevent melting of the core or the wall of the hole.

In the summer of 1957 SIPRE drilled a still deeper hole at the same Greenland site, reaching a depth of 411 meters. Almost all cores were recovered to a depth of 300 meters but beyond that depth only two cores were brought to the surface intact, one from approximately 360 meters depth and one from 400 meters.

Core recovery from such depths is difficult because, as the snow is compressed under the

load of overlying layers, its permeability decreases. At a density of approximately 0.83 the ice becomes impermeable, and with further densification the air in the enclosed bubbles is compressed. When the pressure of the overlying snow reaches 20 kg/cm² at a depth of 230 meters, the bubble pressure is 14 kg/cm², equal to the tensile strength of ice. Drilling releases the confining pressure, causing both the core and the ice forming the wall of the hole to crack. Cracking becomes worse with increasing depth.

The cores from the Greenland drilling have not yet been analyzed completely but annual layers of snow have been identified to the year 1700, ± 10 years, and the age of the deepest core is estimated to be approximately 800 years. In Northeastern Greenland and in Antarctica, where the annual accumulation is much smaller, depths of 300 meters will include 2000 years of frozen history.

Other glacial pit studies and deep core drilling for the IGY program are already underway in the Arctic and Antarctic. Glacial pits have been dug at all the major US stations in the Antarctic. The deepest to date is the pit at the Wilkes Station which was sunk to a depth of 35.25 meters with a drill hole at the bottom of the pit extending another 27 meters.

Part of the equipment required for deep core drilling was delivered to Byrd Station by tractor train on October 24, 1957. The remainder will be delivered by air in the near future. Drilling will start as soon as the equipment is ready.

Other stratigraphic studies will be made by the European International Glaciological Expedition to Greenland, the Canadian Expedition to Northern Ellesmere Island, the US party at the McCall Glacier in the Brooks Range in Alaska, and by other nations at Antarctic stations.

Rocket Flare Patrol Program

Valuable data on solar X-rays during solar flares were obtained during July and August using rockets launched from San Nicolas Island, within the US Navy Pt. Mugu Range, sixty miles off the California coast. The rocket launchings were part of the DAN Rocket Flare Patrol Program, which is designed to determine the radiation source of the radio fadeouts caused by flares on the disk of the sun.

This IGY rocket program was conducted by the Electron Optics Branch of the Naval Research Laboratory (NRL) under the supervision of Herbert Friedman, and with the assistance of T. A. Chubb, J. E. Kuperrian, Jr., R. W. Kreplin, and J. C. Lindsay.

Flare-Upper Atmosphere Relationships

X-rays and Lyman-alpha radiation are two possible sources of the increased ionization responsible for radio fadeout conditions.

X-ray emission from a quiet sun arises in the million-degree coronal gas and consists of recombination continua and line emissions from all the atoms of the coronal atmosphere in their various states of ionization. In an ionization equilibrium at one million degrees Kelvin, the M shells of all atoms are stripped, corresponding to ionization potentials of several hundred electron volts (ev), or wavelengths of 20–100 Å. (The innermost shell of an atom, containing two electrons when filled, is designated the "K shell"; the "L shell," with 8 electrons when filled, lies next to the K shell; and the "M shell," containing at most 18 electrons, is next to the L shell). If the temperature of a local coronal condensation is increased to five million degrees Kelvin, the K shells of the lighter elements up to oxygen may be ionized, corresponding to ionization energies of the order of 1500 ev, or wavelength of about 8 Å. A much greater rise in temperature would be necessary to bring about the excitation of the K shells of Fe atoms. Such temperatures may be produced in flares.

The series limit for the K shell of Fe is 1.4 Å. The abundance of elements heavier than Fe in the solar atmosphere is too small to contribute appreciably to the net X-ray flux. A limit to the X-ray spectrum arising from thermal excitation of the corona may therefore lie in the neighborhood of 1.4 Å for all flares larger than a certain critical magnitude. The rocket discovery of 1–2 Å X-rays in a typical Class 3+ flare implies that the wavelength limit is almost reached by such flares.

In support of the above hypothesis are the observations of Sudden Phase Anomalies (SPA). The SPA is a measure of the drop in the base of the D-region reflecting layer for long radio waves in the earth's upper atmosphere. A maximum drop of 16 km never appears to be exceeded in a wide variety of Class 3, 3+, or even in the rare cosmic ray flares. This height difference of 16 km is of the same order of magnitude as the difference in theoretical depth of penetration of the atmosphere by Lyman alpha ultraviolet rays and X-rays in the 1- to 1.5 Å range. Lyman alpha is responsible for normal D-region ionization. Although an increase in Lyman alpha may account for part of the increased D-region ionization during a flare, it cannot produce the very low-level ionization observed in the SPA. In order for Lyman alpha to produce a 16-km drop in the base of the D region, the total solar Lyman alpha intensity would have to increase by a factor of 10^4 . Since the flare region occupies at most 10^{-3} of the disk, the implication is that Lyman alpha in the flare region increases to 10^7 times the normal value. Such a flux density is virtually impossible astrophysically. X-ray flares can readily account for the magnitudes of observed depressions in the reflecting base.

Radio absorption measurements during Sudden Ionospheric Disturbances (SID) require a five to tenfold increase in total ionization in the absorbing region for Class 2 and 3 flares. The observed X-ray fluxes are

adequate to produce such increases in electron density.

Scientific Results

The scientific results of the program to date are of considerable interest. New geophysical data on solar X-rays have been obtained for flares of Class 1+, 2, and 3+ magnitudes, as well as background data under no-flare conditions. From preliminary inspection of the telemetered data certain features of the X-ray emission are quite clear. A flare produces a marked increase in X radiation of short wave length, or hardening of the X-ray spectrum, compared to that of the quiet corona. The largest flare produced the shortest wavelength X-ray emission, about 2 Å. The total X-ray flux varied from about 10⁻³ ergs/cm²/sec for the Class 1+ flare to about 10⁻² ergs/cm²/sec. for the Class 2 flare. An

estimate has not yet been made of the flux in the Class 3+ flare but it appears that hardness of the spectrum may play a more important role than total flux in accounting for the associated SID.

In every case, an attempt was made to time the rocket firing with the expected maximum phase of the flare. In each firing, therefore, the first few minutes of flare development were by-passed. No evidence has been obtained for large increases in Lyman alpha during any of the flare firings. However, this does not justify ruling out the possibility of a Lyman alpha flash very early in a flare.

Field Operations

The field operation of the DAN Flare Project is of considerable interest as it contrasts with other rocket launching opera-

Table 1. Summary of Results of Rocket Flare Patrol Program

IGY Rocket No.	Date	Altitude (feet)	Sun	Data	Comments
NN7.37F	7/ 1/57	306,000	Quiet	Background, aspect,* γ-rays. No X-rays below 100 km	NACA ignitor; ignitor very rough; large yaw & tumble
NN7.38F	7/ 3/57 0928Z	345,000	Class 1 No SID	Lα, γ-rays, aspect	NACA ignitor; ignitor very rough; large yaw & tumble
NN7.39F	7/15/57 1423Z	90,000	2.5 hr SID	Insufficient altitude, γ-rays	Modified NACA ignitor, failed to ignite Deacon
NN7.40F	7/23/57 1629Z	410,000	Quiet	Aspect, Lα, γ-rays	NRL ignitor plus closure & spinnerons; stable flight
NN7.41F	8/ 5/57 1210Z	40,000	Class 2+	Insufficient altitude	Pre-ignition of Deacon
NN7.42F	8/20/57 0949Z	320,000	Class 1+	Aspect, X-ray	NRL ignitor + closure; large yaw
NN7.43F	8/27/57 0854Z	40,000	Quiet	Insufficient altitude	NRL ignitor + closure; pre-ignition (0.1 sec delay)
NN7.44F	8/28/57 1321Z	410,000	Class 2+ ½ hr SID	Lα, aspect, γ-ray	NRL ignitor + closure; stable flight
NN7.45F	8/29/57 1412Z	420,000	Class 2 ½ hr SID	Lα, X-rays, aspect	NRL ignitor + closure; stable flight
NN7.46F	9/12/57	10,000	Class 2+ 2 hr SID	Insufficient altitude	NRL ignitor + closure; pre-ignition (0.06 sec)
NN7.47F	9/15/57 1327Z		Class 2	Battery failed at take-off	NRL ignitor + closure; visual & photographed flight appeared good
NN7.48F	9/18/57 1042Z	100,000	Class 3+ 2 hr SID	Insufficient altitude	NRL ignitor + closure; Deacon did not ignite
NN7.49F	9/18/57 1054Z	250,000	Class 3+ 2 hr SID	X-rays, aspect	NRL ignitor + closure; rocket tumbled

* Orientation of rocket with respect to sun.

tions. Except for the first few launchings, the field crew has consisted of five to seven men. This crew has been made up partially of personnel from the NRL Optics Division and partially of employees of the Cooper Development Corporation (CDC), contractors to NRL. The NRL crew handled the preparation and installation of the rocket instrument heads, the monitoring of information from the solar observatories, the monitoring of radio fadeout, the firing of the rockets, the telemetering system, and the field analysis and interpretation of the data. They also made auxiliary photographic records of the rocket launchings in the interest of advancing the development of techniques for handling small rockets. The CDC field crew handled the preparation of the two-stage rocket, that is, fitting the crated Nike booster and Deacon bottles with fins and junction fittings, adjusting the rocket fins with spin tabs, preparing Deacon igniters, installing Deacon and Nike igniters, mounting the rockets on the launching frames, operating the launcher, and handling the repeated arming and disarming of the rockets during the daily operations of the group.

In the course of the program, several advances in the technique of using small rockets for research purposes have been accomplished. A new type of aerodynamic telemetering antenna, with uniform radiation pattern, was developed and gave perfect telemetering performance on all flights. Extensive data on the yaw behavior of small

rockets above the restraining influence of atmospheric stabilization have been obtained. The effect of using no second-stage closure (NACA system) on ignition delay and subsequent rocket yaw has been observed and photographed, and a closure system for the two-stage trajectory configuration has been developed. The practicability of command firing of small rockets with only a 60-second delay has been proven. The practicability of rapid repeated firing of small research rockets from a single rocket launcher has been confirmed. Measurements of skin temperature were made. Data were accumulated on the effect of rocket yaw on altitude. Boosters have been visually tracked and some experimental information on the influence of wind on the rocket's trajectory is available. Much detail on rocket behavior is contained in the telemetering records yet to be analyzed.

The success of this project was made possible by the cooperation of the Navy personnel at Pt. Mugu, California. Cdr. O. E. Hearn, USN, designed the launching site and was responsible for all arrangements with the Navy for carrying out the project. The correlation of scientific rocket results with direct solar observations was made possible through the cooperation of Sacramento Peak, High Altitude Observatory, and Mt. Wilson personnel, who observed the sun through the long hours of the rocket operation and maintained the difficult communication links with the island.

Microcard Program for IGY Meteorological Data

The following article is based on material supplied by D. A. Davies, Secretary-General, World Meteorological Organization, Geneva, Switzerland.

The IGY Meteorological Data Centre, in the World Meteorological Organization, is

publishing on microcards the essential meteorological data collected during the 18 months of the International Geophysical Year.

Microcards are standard-size library catalogue cards (75 x 125 mm, 3 x 5 inches) on

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Fig. 2. Typical WMO Microcard Used in IGY Meteorological Program (actual size 3" x 5").

which a number of the original forms (40 to 96) are reproduced in greatly reduced size (see Fig. 2). A special microcard reader, which projects an enlarged image onto a tilted screen, is used for reading the data.

A complete set of microcards of IGY meteorological data consists of four parts, corresponding to the four different types of standard forms on which the essential meteorological data are being recorded. They are:

- Part 1. Synoptic Surface Observations—Land Stations (Form No. 1)
- Part 2. Synoptic Surface Observations—Sea Stations (Forms No. 2 and No. 2(b))
- Part 3. Radiosonde and Rawinsonde Observations (Form No. 3)
- Part 4. Upper Wind Observations (Form No. 4)

Description of the Four Types of Microcards

Form 1, Synoptic Surface Observations—Land Stations, contains 20 surface observations made at a single station during a period of five consecutive days (i.e., one pentade) at the synoptic hours 0000, 0600, 1200, and 1800 GMT. Each Part 1 microcard has room

for a maximum of 96 reproductions of Form 1 arranged in eight rows of 12 forms each; however, the number of forms reproduced on any one microcard will vary between 70 and 90 in order to leave sufficient space for headings, additions, alterations, etc. The forms will be assembled according to the WMO station index numbers. Twenty-five microcards will accommodate the data from 2,000 surface stations; the surface synoptic observations recorded on Form 1 during the 110 pentades of the IGY will, therefore, require a total of 2,750 microcards.

Synoptic surface observations made at sea stations are being recorded on two variations of Form 2. Ships' reports will be written or typed on the basic Form 2, while on the other, Form 2 (b), they will be tabulated from punch cards. Forms containing observations made on board ships at the same synoptic hour will be published together on one or more microcards. It is estimated that about 4,400 Part 2 microcards, reproducing Forms 2 and 2(b), will be sufficient to publish all synoptic surface observations made at sea stations during the IGY.

Radiosonde and rawinsonde observations

are recorded on a standard form, Form 3, which may contain the results of three or four ascents. Microcards on which these forms are reproduced, constituting Part 3 of the set, have room for 40 to 48 forms arranged in five or six rows of eight forms each. Ascents made at the same standard time will be grouped according to the WMO station index numbers.

The largest of these groups in Part 3 will consist of microcards reporting daily ascents made at 0000 and 1200 GMT throughout the IGY. Five to six microcards will probably be needed for each of these two main synoptic hours, making a total of 5,500 microcards for the whole of the IGY.

Reports of ascents made daily at 0600 and 1800 GMT will be reproduced in another, smaller group of about 220 microcards.

Additional ascent data gathered on Regular World Days and in World Meteorological Intervals will be reproduced in a third group of about 280 microcards.

The total number of microcards on which radiosonde and rawinsonde observations will be reproduced (Part 3) will, therefore, approximate 6,000.

Upper wind observations are recorded on a standard form which has space for 10 observations. The microcards on which these forms are reproduced, Part 4 of the set, have room for 40 to 48 forms arranged in five or six rows of eight forms each. Ascents

made at the same standard time will be grouped in the sequence of the WMO station index numbers, preserving as far as possible the same basic regional layout for each of the four main standard times—0000, 0600, 1200 and 1800 GMT—during the whole of the IGY. Microcards containing upper wind data collected during the IGY (Part 4) will total about 5,000.

Complete Set of WMO Microcards for IGY

It is estimated that about 18,500 microcards (including a small margin for possible additions, etc.) will be required to reproduce the essential meteorological observations to be made during the IGY. These are distributed among the four basic data groups as follows:

- Part 1—2,750 microcards
- Part 2—4,400 microcards
- Part 3—6,000 microcards
- Part 4—5,000 microcards

A subscription price of \$5,990 has been established for one complete set of the microcards. Prices for partial sets and individual microcards will be announced at a later date. Orders for microcards may be placed with the World Meteorological Organization, IGY Meteorological Data Centre, 1 Avenue de la Paix, Geneva, Switzerland. Further information about them may also be obtained from this address.

Ionospheric Studies Using Earth Satellites

A conference on study of the ionosphere by means of radio observation of earth satellites was held on November 5, 1957, at the Central Radio Propagation Laboratory (CRPL) of the National Bureau of Standards, Boulder, Colorado. Organized by the USNC-IGY, under the direction of A. H. Shapley, the conference brought together groups that had spontaneously

initiated ionospheric experiments utilizing radio transmissions from satellites launched by the USSR.

The purpose was to enable these groups to discuss their progress, explore refinements in experimental techniques, plan future observations, and discuss problems of reduction and interpretation of measurements made with the first satellites.

Table 2. *Observation of Soviet Satellite Signals*

Agency	Signal Strength Data	Doppler Data	Interferometric and Other Phase-Difference Data	Direction Finding and Radar Data
BRL		20 mc; 0.1-1% slant range accuracy	Two 20-mc interferometers in plane of orbit	
Caltech DTM	20, 40 mc; on tape	20, 40 mc	40-mc phase-switching interferometer data for $\alpha 2$, from Oct. 4; also for β	
Geo. Inst.	20, 40 mc with WWV, from Oct. 4		40-mc total-power interferometer	
HAO	20 mc, 65 passes; on tape (12 in first 24 hours of $\alpha 2$)	20 mc; satisfactory data for 20 passes	20-mc total-power interferometer, Oct. 4-18	
Linc. Lab.	20 mc, Oct. 5-25; 40 mc, Oct. 6-25; exact measurement of frequencies	20, 40 mc; accuracy 2 secs in time, 10 miles in slant range		Radar with $2^\circ \times 2^\circ$ beamwidth; same DF data taken at first; vertical incidence ionospheric soundings
NBS	20 and 40 mc, E-W and N-S; 100 cycle/sec recorder; low angle 40-mc rhombic antenna data; pulse studies	20 mc, 40 mc; calibrated against WWV; accuracy several cycles/sec	Phase-switching interferometers: 40-mc E-W, and 20-mc E-W (double baseline); 40-mc N-S total-power interferometer; continuous phase recording on 1000-ft. baselines; 20, 40 mc, E-W and N-S, circularly-polarized antennas	
Los Alamos	Tape records of $\alpha 2, \beta$	40 mc data using human ear discrimination; 3% accuracy in slope		
NEL			Data from Oct. 5 on N-S & E-W sets of 2 spaced antennas; MK I minitrack adaptation: 20-mc N-S and E-W signal recordings; 40-mc N-S and E-W phase recordings	
NRA			2 dipole E-W interferometers	
NRL		Some data obtained	Minitrack (in operation at Blossom Point, Lima, and San Diego); null times at 20 mc, continuous phase recording at 40 mc; WWV recorded on traces	Radio-telescope altitude data
ASEL and ASRPA	Data from Oct. 4 (aural Oct. 4-7)	Records for Oct. 6-8 at Fletcher's Ice Island, Oct. 8-9 at Thule, Oct. 6-8 on Grand Bahama Island, from Oct. 6 at Adak		Precision 20 and 40 mc; precision DF data from Oct. 5
SRI	20 and 40 mc from Oct. 4 on tape with WWV	Some 20-, mostly 40-mc data from Oct. 4; slant ranges; simultaneous Doppler observations of data		DF: 40-mc for more than one week; 106-mc radar observations
U of Ill.	20 mc on tape, Oct. 4	A few tapes	40-mc records from Oct. 5: N-S (5.45 λ spacing), N-S (1 λ), and E-W (6 λ); 20-mc N-S (5.45 λ) continuous from Oct. 6; N-S data on highspeed instrument to record detailed fading	

Table 2.—*Continued*

Code:

BRL: Ballistics Research Laboratory, Aberdeen, Md.

Caltech: California Institute of Technology.

DTM: Department of Terrestrial Magnetism, Carnegie Institution of Washington, D.C.

Geo. Inst.: Geophysical Institute, University of Alaska.

HAO: High Altitude Observatory, Boulder, Colorado.

Linc. Lab.: Lincoln Laboratories, Massachusetts Institute of Technology.

Los Alamos: Los Alamos, New Mexico.

NBS: National Bureau of Standards, Boulder, Colorado.

NEL: Naval Electronics Laboratory, San Diego, California.

NRA: National Radio Astronomy Laboratory, Green Bank, West Virginia.

NRL: Naval Research Laboratory, Washington, D. C.

ASEL: Army Signal Engineering Laboratory, New Jersey.

ASRPA: Army Signal Radio Propagation Agency, New Jersey.

SRI: Stanford Research Institute, California.

U of Ill.: University of Illinois.

Observations Reported

Representatives of some 24 laboratories and organizations were present at the conference. As an introduction to further discussion they were asked to give short accounts of their observations of the first two satellites, designated $\alpha 2$ and β . Table 2 presents very briefly a résumé of the experiments reported by those participating.

At the time of the Boulder conference, radio transmission from satellite $\alpha 2$ had ceased, but the conference date fell in the middle of the one-week period of transmission from satellite β . Consequently, the entries in the table refer primarily to studies of satellite $\alpha 2$, although in most cases the indicated observations were continued during the period of activity of β .

Signal strength data, as listed in Table 2 include times of appearance and disappearance of radio signals during individual satellite passes. These differ for the two frequencies of signals used. In accordance with theory, under ordinary conditions waves of both frequencies penetrate the ionosphere, but the higher-frequency waves should traverse the ionosphere at greater angles of incidence than those of the lower frequency, and should, therefore, be observed for a longer period of time at ground level. However, this theoretical behavior is actually found to be greatly modified by skip and by anomalous effects not understood at present. The signal levels themselves have been found to be subject to fluctuations, as explained below.

The Doppler effect (col. 3 of Table 2), is well known as the decline in pitch of a railroad train's whistle as the train flashes past the observer. As observed from a fixed ground station, the corresponding decrease in satellite radio frequency during a pass is not only a function of the velocity and position of the transmitting satellite relative to the receiver, but also, according to theory, it is to some degree a function of the ion density along the path between satellite and observer and in the immediate environment of the satellite itself. Hence, interest in such measurements is great.

Typical Doppler curves for $\alpha 2$, recorded at the National Bureau of Standards' Boulder Laboratories, are shown in Fig. 3. The more abrupt the curve, the closer the satellite passed the site of the receiver. Ionospheric effects are also contained in such curves, so that, conversely, if the satellite oscillator is stable and the precise orbit of the satellite is known, ionospheric densities can be deduced from the Doppler shifts. Useful Doppler observations need not be too involved since the human ear functions to excellent advantage in determining the general nature of such curves.

The principle of comparison of phases received over different paths as a means of position determination has been described in some detail in an article on Minitrack equipment in *Bulletin No. 2, August 1957*. Such interferometric observations (col. 4 of Table 2) are subject to fading or fluctuation effects and especially to refraction by

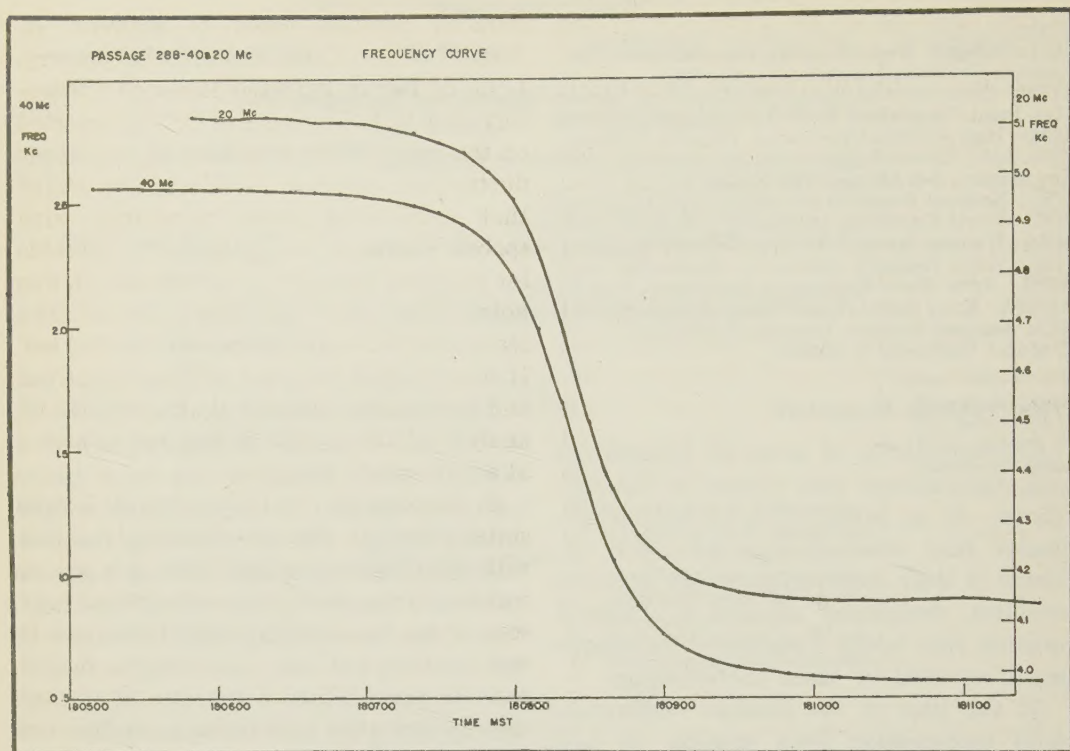


Fig. 3. Doppler Effect at Table Mesa Site, National Bureau of Standards, Boulder, Colorado, on 288th Passage of Satellite 1957 α 2 October 23, 1957.

the ionosphere. Sometimes, so-called total-power interferometers have been used to subtract the fading effects introduced along the transmission path or caused by changes in the relative orientation of the satellite and the observing antennas. In this way, phase variations can be studied separately, without the hindrance of extraneous fluctuations. Interferometric measurements can also be very useful in determining the nature of the upper ionosphere, for, if a precise orbit is known, deviations from expected behavior may be attributed to specific ionospheric phenomena.

In Table 2 are listed radar installations and direction finding instruments. The latter provide data based on signal intensities received at different bearings. (A 400-mc, narrow-beam radar in operation at the Geophysical Institute, University of Alaska, is not listed; no satellite data were obtained there owing to lack of a sufficiently precise satellite-search ephemeris.) Radar observa-

tions of the final phase of satellite orbits would be especially useful. Integrated ion concentrations along radar paths can be deduced from the Faraday effect (rotation of the plane of polarization in the presence of a magnetic field). Thus, the hitherto unknown ion concentrations above the F2-layer maximum can be deduced if knowledge of the ionospheric structure below that level is available.

Although not all of the fifty or more persons participating in the conference had experimental data to summarize, a number of unusual events were reported.

—H. W. Wells of the Department of Terrestrial Magnetism, Carnegie Institution, reported the reception of strong 40-mc signals when the satellite was on the opposite side of the earth. He stated that the half-transit "ghosts" were clean signals and could not have been caused by an occasional cloud or sporadic-E propagation.

—R. M. Gallet of CRPL reported a

sudden decrease of 500 cycles/sec in the basic 40-mc transmission frequency of $\alpha 2$ at the time of the 250th pass, on October 21.

—Louis Burkhardt of Los Alamos noted that a decrease of about one kc in the 40-mc signal of $\alpha 2$ had occurred just before final fadeout. The fadeout itself was observed by several participants to have been gradual rather than abrupt.

—F. R. Dickson, of the Army Signal Radio Propagation Agency, indicated that during one 24-hour period there was continuous reception of satellite transmissions at Adak. (All *passes* during one such period were observed at the IGY South Pole Station.) Dickson also noted anomalies in DF records that appeared to be auroral in origin.

—Doppler frequency curves are sometimes distorted. Some curves plotted at the High Altitude Observatory were reported by D. Billings to have shown a lower maximum rate of decrease than would be consistent with initial and final rates of decrease. This is attributed to ionospheric effects. C. G. Little stated that one out of ten Doppler records at the Geophysical Institute, University of Alaska, shows distortion. Little and W. O. Roberts of the High Altitude Observatory agreed that frequency reversals of Doppler data are seen occasionally, although those observed in Alaska seem to be associated with auroral transmission and occur for only a second or two rather than as long as a minute.

The most general and significant problem of record analysis discussed was that of fluctuations and fading rates. R. N. Bracewell reported that amplitude records at Stanford showed faint CW transmissions between "beeps" received from $\alpha 2$ at long range. He also noted that in order to deduce ionospheric characteristics from observational records, fading owing to such mechanical factors as satellite spin or attitude would necessarily have to be extracted so that the influence of such factors as rapid auroral fluctuations or variations resulting from the

Faraday rotation could be assessed. R. Jastrow of the Naval Research Laboratory, L. G. de Bey of Ballistics Research Laboratory, and R. S. Lawrence of CRPL, reported on the wide variety of phase and amplitude fluctuations observed. J. Herbstreit stated that continuous phase recordings with spaced antennas are potentially valuable for studying ionospheric turbulence. It was noted that some preferred periodicities seemed to be about $1\frac{1}{2}$ sec and 4 or $4\frac{1}{2}$ sec. It was pointed out that antenna polarities and orientations are such that a very subtle analysis of the records is required to arrive at a proper interpretation.

E. Hayden of the University of Illinois stated that observations frequently began with scintillations, which later changed to regular fading, leaving one-sec fluctuations superposed on a four-sec rate. Fade periods rapidly decreased as the satellite passed out of range. On 20-mc interferometer records, precursor fluctuation patterns were often observed in the afternoon before the actual interference pattern appeared. W. O. Roberts, of the High Altitude Observatory, stated that HAO records also showed such behavior, but in the opposite order. On some evening passes signal strength increased as the satellite receded, according to W. S. MacDonald, of the California Institute of Technology. It was agreed that maximum signal strength is not useful as an indication of time of closest approach.

Suggestions and Recommendations

Considerable discussion at the conference concerned the role radio amateurs might play in satellite observations. In general, it was felt that the observation of in and out times, rough signal strengths, and perhaps Doppler observations—preferably with a common, general, standard-reference frequency—might be useful, particularly in connection with long-range propagation effects. It was informally suggested that George Grammer, who was present as representative of the Amateur Radio Relay

League, might formulate the precise program. Amateurs would be asked to perform their own data reduction but the ARRL might act as a clearing house to accept and examine their reduced data.

Participants at the conference asked IGY satellite-tracking organizations to indicate the kinds of supplementary data which would be useful to them. They also requested that orbital and prediction data be distributed widely, rapidly, and in a form readily usable at each station; it was desired that precision estimates accompany the data. Observers were themselves asked to submit comparisons of satellite prediction and observation to the Smithsonian Institution and the Naval Research Laboratory.

The need for simultaneous optical and

radio satellite observations was emphasized; any data fixing the orbit more precisely is helpful in extracting ionospheric information. Simultaneous ionosonde and radio observations would also be most useful. It was strongly urged that satellite transmission frequencies be stabilized as much as practicable to permit the extraction of the maximum quantity of ionospheric information from precision Doppler data. The desirability of having some future satellite transmissions at frequencies of the order of 20 mc, with known modulation as a control experiment, was recognized by all. There was also an extended discussion of the comparative usefulness of Doppler and Minitrack observations for obtaining orbital data.